FACTORS AFFECTING THE STORAGE LIFE OF BARTLETT, MAGNESS, AND MOONGLOW PEARS

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ABSTRACT

Pears stored near 0°C at high relative humidity (rh about 95 percent) developed more core breakdown but less surface scald than those stored at lower rh's (90 and 85 percent). Breakdown usually was not evident until after the pears had ripened at 18°. Some scald was present when the pears were removed from 0° storage, and the severity increased during ripening. 'Bartlett' pears developed core breakdown after 2 months of storage and ripening, compared with 4 months for 'Moonglow' and 'Magness'. Moonglow developed the least amount of breakdown but the greatest amount of scald. Pears stored at the lowest rh lost the most weight and were softer after storage than those stored at the highest rh. Date of harvest had little effect on breakdown, scald, or soluble solids content. The intermittent warming treatment (24 hours at 18° after 1, 2, or 3 months of 0° storage) had no significant effect on shrivel, scald, core breakdown, or soluble solids content. Decay was not severe until after 4 months of storage and ripening. Decay was not affected by rh during storage, but more developed in pears which received the intermittent warming treatment than in those stored constantly at 0°.

INTRODUCTION

Numerous studies report that most pear cultivars should be stored at -1° to 0°C (4, 5, 10, 11, 12, 13, 15, 16, 18, 19). During storage, disorders such as "scald" and "core breakdown" frequently develop. Causes of these disorders are not known, but it is believed that growing season, maturity, storage temperatures, atmospheres and duration, and cultivar contribute (2, 4, 10, 11, 12, 13, 14, 17). Two recently introduced pear cultivars, Magness and Moonglow, are highly resistant to Erwinia amylovora (Burrill) Winslow et al., the causal organism of fire blight of pome fruits. This disease is serious, or potentially so, in most of the pear-growing areas of the world. There is no information on the storage behavior of fruit of these cultivars.

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Several papers emphasize the importance of high relative humidity (rh) as well as low temperature in preserving the storage life of several commodities (8, 21, 22, 23, 24). In addition, when some types of produce are warmed at intervals during low temperature storage, certain physiological disorders are lessened or prevented (1, 9). In this report Bartlett, Magness, and Moonglow pears were used to find the effect of rh and intermittent warming, or a combination of both, on physiological disorders of pears.

MATERIALS AND METHODS

In 1975, Bartlett, Magness, and Moonglow pears were obtained from the orchards at Beltsville, Md. Each was harvested on four dates: about 2 weeks and 1 week before recommended harvest, at the recommended harvest date, and 1 week after the recommended harvest date. At each harvest, samples of 35 to 40 pears of each cultivar, free of major blemishes and decay, were placed in trays for storage. Maturity was determined in 20 other comparable pears by use of a Magness-Taylor pressure tester fitted with a 7.9-mm (5/16-inch) plunger and by external and internal visual examination. Twenty additional samples of each cultivar were held at 18°C for ripening and measurement of color, flavor, general appearance, pressure (firmness), and external or core breakdown.

Trays of pears from each harvest were stored in chambers near 0°C and relative humidities of about 95, 90, and 85 percent. Humidity in the high rh chambers was maintained with a mechanically controlled humidifying unit. For the lower rh's dry air was mixed with the humidified air. Within each humidity chamber, for each harvest, and for each cultivar the pears were stored as follows:

1. Constantly at 0°C for 4 months.
2. One month at 0°C, then warmed at 18° for 24 hours and returned to 0°.
3. Two months at 0°C, then warmed at 18° for 24 hours and returned to 0°.
4. Three months at 0°C, then warmed at 18° for 24 hours and returned to 0°.

Data on weight loss, general appearance, ripening, firmness, skin color, seed color, soluble solids, taste, shrivel, scald, external and core breakdown, and decay were recorded for samples of the pears when they were removed from 0°C storage after 2, 3, and 4 months, and after they were subsequently held for 6 or 7 days at 18°. Shrivel, scald, and external and core breakdown were rated on the following scale: 1 = no disorder,

2 = trace, 3 = slight, 4 = moderate, 5 = severe, and 6 = extremely severe disorders. A hand refractometer was used to measure soluble solids as an estimate of sugar content.

RESULTS

1975 Season

At harvest, the skin of Bartlett pears was a light yellowish green while the skin of Magness and Moonglow was green. Flesh of each cultivar was white, hard to firm, and smooth. The flesh of Moonglow contained numerous light green streaks. Shortly after cutting, the flesh of all three turned tan to brown, with that of Magness the darkest. Seedcoats of all three cultivars at the first harvest and those of Bartlett at the second harvest were cream to white. The seedcoats of Magness and Moonglow pears at the second harvest were tan to brown, and at later harvests the seedcoats of all cultivars were brown to black.

On removal from storage the skin of Bartlett pears was light yellow and of Magness and Moonglow pears, a yellowish green. The longer they were stored at 0°C, the more yellow the skin color. Fruit intermittently warmed usually developed more yellow skin color during storage than fruit held constantly at 0°. After storage, regardless of the harvest date or length of storage, the seedcoats of all cultivars were brown to black, but the appearance of the flesh was about the same as that of freshly harvested pears. On ripening at 18° the skin of the Bartlett pears was completely yellow and that of the other two cultivars was a yellowish green.

At each of the harvests, Bartlett pears were firmer than the other two cultivars, and Moonglow were the softest (table 1). With each cultivar, fruit from the first harvest were firmest. Fruit firmness at the other three harvests did not differ significantly but fruit tended to be softer at later harvests. Usually, Bartlett and Magness pears softened about 1.7 kg (4 pounds) during 4 months of storage, but Moonglow pears softened very little if any (table 1).

After 4 months of storage, firmness of the pears on removal from 85 percent rh was lower than that of pears from the two higher rh's, and that of Bartlett higher than the other two cultivars regardless of rh (table 2). Firmness of pears held constantly at 0°C was higher than that of pears given any of the intermittent warming treatments (table 3). Fruit warmed after 1 month were significantly firmer than those warmed after 2 months of storage, while fruit warmed after 3 months were the softest of any of the warmed fruit. Likewise fruit held at the lowest rh were the softest. Regardless of cultivar, harvest time, humidity, or warming period during storage, all pears softened to below 1.3 kg during the ripening period at 18°.

TABLE 1.--Firmness of pear cultivars harvested on different dates[1/][2/][3/]

Harvest	Firmness at harvest			Harvest mean	Firmness after 4-month storage			Harvest mean
	Bartlett	Magness	Moonglow		Bartlett	Magness	Moonglow	
	kg	kg	kg	kg	kg	kg	kg	kg
1	8.8	7.5	6.3	7.5 A	7.2	6.5	5.6	6.4 A
2	7.8	6.8	5.7	6.8 B	6.0	5.2	4.1	5.4 B
3	7.8	7.0	5.7	6.7 B	5.9	5.1	5.2	5.1 B
4	6.9	6.3	4.9	6.3 B	5.2	4.0	5.0	4.8 B
Cultivar mean--	7.8 A	6.9 B	5.6 C	---	6.1 A	5.2 B	5.0 B	---

1/ Firmness determined with Magness-Taylor pressure tester 7.9-mm (5/16-inch) diameter plunger.

2/ To convert kilograms to pounds, multiply by 2.205.

3/ Numbers within box are average of 20 fruit at harvest and 60 after storage. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letter in common are significantly different.

Table 2.--Firmness of pear cultivars after 4 months' storage at 0°C at different relative humidities (rh)[1/][2/][3/]

Relative humidity (percent)	Firmness of: Bartlett	Magness	Moonglow	Rh mean
	kg	kg	kg	kg
95----------	5.7	4.7	4.9	5.1 A
90----------	5.7	4.7	4.9	5.1 A
85----------	5.6	4.9	4.4	4.7 B
Cultivar mean---	5.7 A	4.8 B	4.8 B	---

1/ Firmness determined with Magness-Taylor pressure tester 7.9-mm (5/16-inch) diameter plunger. Before storage, firmness was 7.5, 6.6, and 5.4 for Bartlett, Magness, and Moonglow, respectively.

2/ To convert kilograms to pounds, multiply by 2.205.

3/ Numbers within box are average of 80 fruit. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letter in common are significantly different.

Table 3.--Mean firmness of Bartlett, Magness, and Moonglow pears after 4 months' storage in different relative humidities (rh) at 0°C constantly or with intermittent warming at 18° [1/][2/][3/]

Relative humidity (percent)	Firmness after storage regime of: 0°C constantly	Intermittent warming after 1 month	Intermittent warming after 2 months	Intermittent warming after 3 months	Rh mean
	kg	kg	kg	kg	kg
95----------	6.0	5.1	4.7	4.6	5.1 A
90----------	5.9	5.4	4.7	4.5	5.1 A
85----------	5.5	4.6			
Storage mean----	5.8 A	5			

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Weight loss also was affected by rh during storage and by intermittent warming treatment. The cultivars did not differ significantly in weight loss. The most weight was lost by the pears stored 4 months at 85 percent rh and the least, by pears stored at 95 percent (table 4). Essentially the same amount of weight was lost by pears stored constantly at 0°C and those intermittently warmed at 18° after 1 month of storage (table 5). Weight loss of pears warmed after 2 or after 3 months of storage did not differ from each other, but they lost significantly more weight than those held constantly at 0° or those warmed after 1 month at 0°. Regardless of the storage regime, Bartlett pears lost more weight than either of the other two cultivars. The time of harvest had no significant effect on the weight lost by the pears during storage.

Only a slight amount of shrivel developed, and it was not apparent until after 4 months of storage. Since the cultivars did not differ significantly in weight loss, shriveling of the cultivars was apparently independent of weight loss, but it was related to rh of the storage chamber atmosphere. Moonglow developed slightly, but significantly more, shrivel than either of the other cultivars, which developed essentially the same amount (table 6). Regardless of cultivar most shrivel developed on pears stored at 85 percent rh and the least on those stored at 95 percent rh. When shrivel occurred it was at the stem end and usually was not apparent throughout the rest of the fruit.

Table 4.--Percent weight loss from pear cultivars stored constantly for 4 months at 0°C at different relative humidities (rh)[1/]

Relative humidity (percent)	Weight loss of:			Rh mean
	Bartlett	Magness	Moonglow	
	Percent	Percent	Percent	Percent
95----------	0.7	1.6	1.4	1.2 C
90----------	2.4	2.8	3.4	2.9 B
85----------	4.5	4.2	4.8	4.5 A
Cultivar mean---	2.5 A	2.7 A	3.3 A	---

1/ Numbers within box are averages of 80 fruit. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letters in common are significantly different.

Table 5.--Percent weight loss from pear cultivars stored 4 months at 0°C with intermittent warming at 18° 1/2/

Storage regime	Bartlett	Magness	Moonglow	Storage mean
	Percent	Percent	Percent	Percent
0°C constantly-------	1.1	1.1	1.1	1.1 A
Intermittent warming after 1 month------	1.8	.8	1.6	1.4 A
Intermittent warming after 2 months-----	2.4	2.4	1.3	2.2 B
Intermittent warming after 3 months-----	2.8	1.3	1.7	1.9 B
Cultivar mean------	2.2 A	1.3 B	1.4 B	---

1/ Pears stored at 0°C and warmed at 18° for 1 day at the end of each month and then returned to 0° (intermittent warming).

2/ Numbers within box are averages of 60 fruit. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letter in common are significantly different.

Table 6.--Shrivel ratings of pear cultivars stored 4 months at 0°C at different relative humidities (rh) 1/2/

Relative humidity (percent)	Rating of:			Rh mean
	Bartlett	Magness	Moonglow	
95------------------	1.0	1.0	1.1	1.0 C
90------------------	1.1	1.2	1.6	1.3 B
85------------------	1.3	1.5	2.0	1.6 A
Cultivar mean------	1.1 B	1.2 B	1.6 A	---

1/ Shrivel rating on scale of 1 = no shrivel, 2 = trace, 3 = slight, 4 = moderate, 5 = severe, and 6 = extremely severe.

2/ Numbers within box are averages of 4 samples of 30 to 35 fruit each. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letters in common are significantly different.

Moonglow pears had a mean scald rating of 2.9 and 3.2 when they were removed from 2 and 3 months of storage at 0°C. At those removals, no scald had developed on the other cultivars. As the time in storage increased, the severeity of scald increased. Some was present on Bartlett pears on removal from storage after 4 months, but none developed on Magness pears during storage. Scald developed on all pear cultivars when they were ripened at 18°. It was more severe after ripening than immediately after storage. More scald developed on pears during storage and during ripening when pears were stored at 85 percent rh rather than at 90 or 95 percent rh (table 7). Time of harvest had slight to no effect on scald development. After 4 months of storage, the ratings for Bartlett were 1.0, 1.4, 1.7, and 2.2, and for Moonglow 3.7, 3.8, 3.3, and 3.7 for harvest 1, 2, 3, and 4, respectively.

Core breakdown was slight to not visible when the cultivars were removed from storage regardless of harvest period, duration of storage, warming treatments, or relative humidity during storage. After 2 months of storage at 0°C and ripening at 18°, Bartlett pears had a core breakdown rating of 2.4. No breakdown developed in the other two cultivars until after they were stored 4 months at 0° and ripened at 18°. Breakdown in Bartlett pears was severe to extremely severe and sometimes moderate to severe in Magness pears, but only trace to slight in Moonglow pears (table 8). About the same amount of breakdown developed regardless of the time of harvest. When breakdown occurred it was most severe in pears stored at 95 percent rh and least in those stored at 85 percent rh, regardless of the length of storage. The effect of rh during 4 months of storage was much more pronounced with Magness and Moonglow than with Bartlett pears.

In many cases core breakdown was visible externally. The earliest symtom was a water-soaked, greenish discoloration of the skin near the blossom end of the pears. Flesh beneath this discoloration was water-soaked to light tanish pink, and somewhat jellylike. This breakdown apparently progressed into the area surrounding the seed carpels and into the flesh of the pears as a tanish pink, somewhat translucent or apple-jellylike breakdown. In severe cases the seed carpels and affected flesh could be scooped out, leaving a saucerlike cavity.

Tests for soluble solids in the juice of pears (as estimate of sugars) were conducted with a refractometer on pears from the second, third, and fourth harvests. After these fruit had ripened at 18°C, neither the harvest date nor the relative humidity during the 0° storage affected the soluble solids. The soluble solids for Bartlett, Magness, and Moonglow after 4 months of storage at 0° and ripening at 18° averaged 10.3, 13.9, and 11.0, respectively.

The intermittent warming treatment had no significant effect on shrivel, scald, core breakdown, or soluble solids of the pears (data are not presented).

Decay was of minor importance in each pear cultivar until pears were stored 4 months at 0°C and then ripened at 18°. At that time, though the differences were not statistically significant, Bartlett pears had the most decay and Moonglow pears, the least. Intermittent warming treatment did significantly affect decay, with the percent of decayed pears averaging 36,

Table 7.--Scald ratings of pear cultivars stored 4 months at 0°C at different relative humidities (rh)[1/2/]

Relative humidity (percent)	Rating on removal from 0°C			Rh mean	Rating after ripening at 18°C			Rh mean
	Bartlett	Magness	Moonglow		Bartlett	Magness	Moonglow	
95	1.2	1.0	3.3	1.9 B	3.9	1.4	4.7	3.3 B
90	1.2	1.0	3.7	2.0 B	4.0	1.4	4.8	3.4 B
85	1.5	1.0	3.8	2.2 A	4.3	1.4	5.2	3.6 A
Cultivar mean	1.3 B	1.0 B	3.6 A	---	4.1 A	1.4 B	4.9 A	---

1/ Scald ratings on scale of 1 = no scald, 2 = trace, 3 = slight, 4 = moderate, 5 = severe, and 6 = extremely severe.

2/ Numbers within box are average of 4 samples of 30 to 35 fruit each. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letters in common are significantly different.

51, 53, and 54 for the constant 0° storage, and warming periods after 1, 2, and 3 months of storage, respectively. Neither the date of harvest nor rh during the storage period had any significant effect on decay of the pears.

Table 8.--Core breakdown ratings of pear cultivars after 4 months' storage at 0°C at different relative humidities (rh) and ripening at 18°[1/][2/]

Relative humidity (percent)	Rating of: Bartlett	Magness	Moonglow	Rh mean
95----------	5.8	4.4	2.4	4.1 A
90----------	5.5	1.8	1.6	3.0 B
85----------	4.9	1.4	1.6	2.7 C
Cultivar mean---	5.4 A	2.5 B	1.9 B	---

1/ Core breakdown ratings on a scale of 1 = no breakdown, 2 = trace, 3 = slight, 4 = moderate, 5 = severe, and 6 = extremely severe.

2/ Numbers within box are averages of 80 fruit. Duncan's Multiple Range Test letters are for significance at the 5-percent level. Comparable means followed by no letters in common are significantly different.

1976 Season

In 1976 a similar but less extensive study was conducted with single harvests only of Bartlett and Magness pears grown in Maryland. In this test the effect of intermittent high (90 percent) and low (80 percent) rh on weight loss, appearance, and breakdown was determined after 2 and 4 months' storage at constant temperature (0°C). Rating scales for scald and breakdown were the same as in 1975.

Results in the second year in part confirmed the earlier results. Severe scald developed on the Bartlett pears regardless of rh, but essentially no scald developed on the Magness pears. The type of scald differed from that of the previous year. It was dark brown to black, especially severe at the blossom end of the fruit, and rather firm to dry. It closely resembled senescent scald rather than the storage scald of the previous year. Pears in this test were severely scalded when they were removed from storage after 4 months and during holding at 18°C.

breakdown. Development of core
For Bartlett pears, core breakdown
rcent rh, respectively, after 2
arming at 18° and 5.1 and 4.8 after
kdown). Corresponding external
2 months' storage. Magness pears

did not develop external, and only a little core, breakdown until after 4 months of 0° storage and the ensuing ripening period at 18°. Then only a few of the pears had slight to moderate core breakdown with ratings of 3.9 and 3.4 for 90 and 80 percent rh, respectively.

The interruption of rh by a change from high to low for a week and vice versa had no effect on weight loss, ripening rate, scald, or external or core breakdown.

DISCUSSION

This study presents information on storage life, conditions, and disorders of Bartlett, Magness, and Moonglow pears.

The rapid development of core breakdown of Bartlett pears we noted agrees with other findings (7, 11, 12, 13, 15, 16, 19). We monitored the rh during our studies and found that core breakdown was more severe in pears stored at high than at low rh. This agrees with a report that pears stored in boxes with polyethylene liners (presumed high rh) had more core breakdown than those stored in open boxes (presumed low rh) (3). The influence of high rh on core breakdown of pears corresponds to that of high rh on internal breakdown of apples. Conditions which prevent weight loss of apples reportedly increased low temperature breakdown (26, 27). Low temperature breakdown of apples also was reported to be far more severe when the fruit were stored at rh of 90 percent and above than at lower rh's (20). The reason for the increased breakdown of apples and pears at high rh is not known.

In our studies, external symptoms of core breakdown appeared near the blossom end of the pears. A softening of Bartlett pears at the blossom end was previously attributed to low temperatures during the growing season (25). Core breakdown was found to be more prevalent when pears are grown in cool than in warm areas (6, 12). Since the pears in both our test years were grown at or only a short distance from Beltsville, we believe that a cold growing season was not responsible for this abnormal form of core breakdown.

Core breakdown has been attributed to many other causes such as pear maturity, storage temperature, crop size per tree, buildup of acetaldehyde, and delay in cooling (3, 4, 7, 10, 11, 13, 15, 16, 17, 18). Our data do not agree with many of these findings, since about as much breakdown occurred in the early- as in the late-harvested fruit. In 1975, at least, the fruit were cooled within a few hours of picking. In 1976, there was a delay between harvest and proper cooling, and this delay may have contributed to the severe breakdown that occurred with Bartlett pears. No records were obtained on crop size, but it is judged that the fruit came from heavy-bearing trees. Temperatures of our storages usually were slightly above 0°C and may thus contribute to the higher amounts of breakdown. We did not measure acetaldehyde buildup.

Our studies also compared storage quality of Magness and Moonglow with Bartlett pears. Certain pertinent facts were uncovered. Magness pears at each of the relative humidities held up better than the other two cultivars. Core breakdown, even at the highest relative humidity, was considerably less

than in Bartlett pears, and then it did not develop until after 4 months of storage near 0°C plus ripening at 18°. No scald developed during storage, and only a small amount developed during the ripening period. The soluble solid content of the Magness cultivar was higher than that of the other two, and it was not affected by time of harvest or length of storage. Generally, at each removal date, the fruit ripened to high quality. Moonglow, on the other hand, developed severe scald within 2 months of storage and ripening, and by the end of 4 months of storage and ripening the scald made this cultivar unacceptable. Moonglow, however, had the least core breakdown of the three cultivars. Taste of Moonglow at each removal date was questionable. The fruit never really softened, and though it was very juicy, it often had an astringent and disagreeable flavor. More studies are needed, particularly in respect to harvest maturity and and storage quality of Moonglow.

Our studies do not agree with previously published data on the effect of harvest dates on scald, core breakdown, and soluble solid content. This is difficult to explain. Possibly our sampling at the various harvest dates did not truly obtain fruits of different maturities as reported by other workers. A better method of determining maturity than pressure testing and days from bloom is greatly needed. Perhaps the temperature effects during the growing season should be more carefully considered to accurately determine changes in maturity (14).

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